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Additional submitted attachment is included below.

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(via Docket # 17-BSTD-01)

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Introduction:

AccurIC again welcomes the opportunity to respond to proposed draft amendments to the 2019 Building Energy Efficiency Standards. As the Commission will be aware, AccurIC has been a regular responder to proposals made in respect of the lighting section of the standards, keen as it is to ensure that low-energy lighting technology, including LED, is introduced into wide circulation in a manner which is acceptable to the public. We have continued to stress throughout the standards development process within the State of California, the need for the excellent work of the Commission, to be underpinned by peer-reviewed research and peer-reviewed standards.

With this in mind, we wish to comment on proposed changes to the draft 2019 standards, relating to the measurement and recording of photometric flicker and in particular, to proposed changes to Joint Appendix JA8.

Comments on proposed amendments to Joint Appendix JA8:

The current proposal that manufacturers may either submit flicker data in the form requested in Table 10.1 of JA10 or provide a single metric (SVM) sets up a false equivalence between that which is measured by SVM and that which is recorded in Table 10.1. Specifically:

1. SVM (Stroboscopic Visibility Measure) as its name suggests, considers photometric flicker, at frequencies above 80Hz, only to the extent that it is directly visible, via the stroboscopic effect. Table 10.1, by contrast, makes no such restriction – it simply asks for the data. Table 10.1 therefore enables assessments and comparisons to be made, by reference to peer-reviewed standards and recommended practices, such as the (now widely accepted ANSI standard) IEEE Std 1789. This IEEE recommended practices document sets acceptable limits on photometric flicker, by reference to a wide range of peer-reviewed research, covering not only directly visible effects, but also physiological effects, such as headache, migraine and malaise.

2. The formulation of SVM, in the context of either single-tone or multi-tone modulation, relies upon the use of a human eye sensitivity curve, which relates to highly controlled circumstances. Specifically, circumstances in which the observer is stationary – thereby ignoring the 'phantom array' effect, which is, after all, a type of stroboscopic

detection (one in which the observer, or at least their head or eyes) is/are moving relative to the flickering light source. It is therefore difficult to see how such a metric can capture useful data relating to real circumstances. Human beings tend to move and furthermore, the human eye is in an almost perpetual state of movement (saccades)

3. The human eye sensitivity curve, used for setting acceptable levels of stroboscopic flicker represents the 50% detection boundary. It is the level of modulation at each frequency, at which 50% of the population can detect the stroboscopic effect. Consequently, the 'acceptable' level of SVM is the level at which stroboscopic effects are visible to 50% of the population. In the development of any flicker standard, this has to be considered as a very low 'hurdle'. Does, for instance, the State of California wish to see the proliferation of lighting products, which give rise to visible stroboscopic effects for half the population, whilst (more importantly, perhaps) not accounting for non directly-visible effects?

4. In the context of multi-tone modulation (e.g. when a PWM dimming or control tone is present, as well as modulation via rectified mains) the SVM is formulated as:

   $$SVM = \sqrt[3.7]{\sum \left(\frac{C_m}{S_m}\right)^{3.7}}$$

   Where, C_m = amplitude of Fourier component, m and Sm = sensitivity (threshold amplitude of a sinusoid) at tone m

   SVM therefore attempts to capture a statistical composite measure of the visibility of flicker occurring at various frequencies, in a way which results in an unfair penalisation of a lighting source which uses multiple modulations, even when each tone has a modulation-depth that lies within (under) the sensitivity curve

   By way of example, consider a lighting system in which there are 3 modulating tones, each with a modulation depth which is 90% of the sensitivity limit for that tone (each modulation, therefore, is below the direct visibility threshold used as the basis of SVM). The resulting value of SVM is then:

   $$SVM\ for\ 3 - tone\ modulation = \sqrt[3.7]{3x0.9^{3.7}} = 1.2$$

   Therefore, despite the fact that each tone lies within (below) the visible limit, the resulting value of SVM exceeds 1.0, thereby breaking the limit (1.0). Insofar as this has been explained, via the work of Perz et al (Lighting Research Technology, 2015; Vol 47; 281-300) it has been so in the context of complex repetitive waveforms, and more specifically, square waveforms, comprising frequencies which are therefore harmonically-related (these being the Fourier components of the complex waveform). Such an approach would seem reasonable, both a-priori and in light of measurements made by Perz et al using repetitive square waves, comprising harmonically-related Fourier components. Conversely, where there are tones present which are not harmonically-related, there would be no reason to believe, or indeed assume, that their contribution to the stroboscopic effect would be additive. However, it is unclear from either NEMA 77, or the proposed amended JA8, how a lighting system would be tested against SVM, if there is more than one modulating tone present and where the modulating tones are not harmonically-related (for a real-world example, modulation at twice mains frequency and at a PWM dimming frequency, which is not a multiple of twice mains frequency). It is therefore entirely unclear how a lighting system in which non harmonically related modulation tones are present can be represented, in terms of the stroboscopic effect, by way of a single SVM value, as proposed in the amended JA8. Furthermore, an independent assessment should be carried out to assess whether the Matlab code presented in NEMA 77 allows for such a situation and if so, how it is dealt with

5. The proposed use of NEMA 77 as an alternative to the recording of data specified in JA10, would, if adopted, negate the requirement of JA10, that flicker data be measured not only at full output and 20% dimmed, but also at the lowest (deepest) dimming point available for the product under test. In view of the fact that, for the majority of dimmable lighting products, flicker contrast levels increase with dimming, this would represent a serious omission.

6. In view of the fact that NEMA is an industry body, the proposed adoption of SVM, via NEMA 77 should be reviewed by experts within the field of light perception, including flicker perception, outside the lighting industry. Unless and until such a review has taken place successfully, NEMA 77 should not be presented as being on an equal footing with the ANSI Standard, IEEE Std 1789, the recommendations of which underpin the measurement requirements given in JA10.

Conclusion & recommendations:

1. NEMA 77 cannot, in our view, be seen as equivalent to, and therefore an alternative to, that which is captured by Table 10.1 of JA10. The data captured by the first relates only to flicker which is directly visible, by a stationery observer, whereas the second includes all flicker effects, including physiological effects and 'phantom arrays'. Also, JA10 requires the recording of flicker at the deepest dimming point of a product, whereas the proposed alternative use of NEMA 77 does not. Therefore, the assumed equivalence does not stand.

2. The use, in the formulation of SVM, of an eye sensitivity curve based on a 50% direct detection rate, and which takes no account of well documented physiological effects of flicker arising from indirect-detection, seems overly permissive for a metric which is being proposed as an alternative to the publication of flicker data which allows for comparison both between products and with a rigorously reviewed ANSI standard such as IEEE Std 1789

3. In view of the above, NEMA 77 should only be presented as an additional (as opposed to alternative) method of presenting flicker performance data, once it has undergone rigorous external peer-review, in the same manner as IEEE Std 1789.

4. In light of the above, we respectfully submit that the proposed amendments to Joint Appendix JA8, which allow for the substitution of NEMA 77 measurements in place of the measurements specified in Table 10.1 of JA10, should be struck out. We furthermore recommend that the use of NEMA 77 in addition to the Table 10.1 data should only be considered following external review of NEMA 77, by experts in the field of photometric flicker and TLAs, outside of the lighting industry.